MOMENT RESISTANT STRUCTURE WITH SUPORTING MEMBER AND METHOD FOR THE SAME

BACKGROUND OF THE INVENTION

1. Field of The Invention:

The present invention relates to a moment resisting structure with supporting members and fabricating method thereof for intensifying moment resistant performance of the structure. The supporting members each at an end thereof are attached to a supported member and at another end thereof are together with the supported member being joined to connecting elements in the vicinity of structural moment resisting connections. The supporting members resist deflection of the supported member at support spots and generate reactions to well-distribute bending moments endured by the supported member such that the structure, which is composed of the supported member, the supporting members and the connecting elements, is capable of providing better moment resistant capability. The present invention is especially suitable for a structure formed of rigid frames for supporting members such as beams, which primarily resist bending moments so that the present invention can be applied to steel structure or steel reinforced concrete structure to strengthen new building construction or the like.

2. Description of Related Art:

For a structure composed of rigid frames, members thereof are connected by way of moment resistant capability. When the structure is subjected to lateral load such as earthquake force, wind force or the like, it endures bending moment as shown in Fig. 1a or when a horizontal member is subjected to vertical load, it endures bending moment as shown in Fig. 1b. It can be seen in Figs. 1a and 1b that joints of the members and other structural elements such as connecting elements or bases endure larger bending moments than elsewhere. According to the conventional arts,

the members are arranged based on a result of structural analysis for various load combinations and design moment resistant strength for the members to exceed bending moments occurred under various load combinations.

It is found in earthquake disasters happening in recent years that a structure at joints of members thereof or in the vicinities of the joints occurs phenomena of brittle fractures. For instance, beam-to-column connections of the steel structure are damaged seriously in earthquakes of Northridge, U.S. in 1994 and Kobe, Japan in 1995. It is found out from investigation of these two earthquakes that joints of members are weakest points of a structure and the quality of welding job is hard to be controlled. When the structure is subjected to an earthquake, stress concentrates at the joints of the members and it results in connected columns being deformed such that flanges of the beams are subjected to extremely strong shear forces in addition to being subjected to original designed flexural stress. Thus, it generates the brittle fractures, which are caused by inadequate strength of welding or effect of heat due to welding. The phenomenon and several solving alternatives have been described in FEMA-350, 2000, Recommended Seismic Design Criteria for New Steel Moment-Frame Building.

In order to avoid brittle fractures, a principle of structural design is applied and the principle is featured in that uniform material stress at a spot of maximum bending moment can be obtained during load increasing on a member. In this way, the member yields after the stress exceeding elastic strain zone and the yielding location is an area instead of a spot so that ductility of the member can be increased and the area is called plastic hinge. In addition to the preceding FEMA-350, structure regarding increasing ductility of beam-column connection has been disclosed in U.S. Patent Nos. 5,913,794, 5,680,738, 6,012,256 and 6,138,427 and Taiwanese patent application No. 85204600.

Currently, there are two categories of methods for the steel structure solving

the problem of inadequate ductility of traditional beam-column connection, namely, one is stiffened beam section connection, with which a location occurring the plastic hinge can move outward to outside a stiffened element by way of increasing the bending moment at the beam-column connection, and the other one is reduced beam section connection, with which the plastic hinge can occur at a strength decreases zone by way of part of flange of the beam being reduced the cross section thereof. However, the stiffened beam section connection is incapable of not only improving the problem of stress concentration at the connection but also improving the problem of controlling weld quality. The reduced beam section connection results in the cross section of the member decreasing so as to need a member with larger cross section.

The eccentric bracing steel structure is a seismic resistant structure, with which bending moments and shear forces can be transmitted to columns by way of bracing, and, it can control lateral displacement of the structure and provides more ductility than that of the ordinary bracing structure. However, there is a small section of the beam being subjected to extremely strong shear force so that the bracing results in increased structural cost and leads to being used inconveniently.

In order to deal with moment resisting frame in the currently utilized reinforced concrete structure, both ends of each member is treated to have greater bending moments and more steel bars are arranged at the two ends. However, it is inconvenient for construction because of densely placed steel bars and, also, it affects the construction quality. Moreover, it is necessary to enlarge the cross section of the member but the self-weight of structure becomes heavier and occupying excessive space. The earthquake of Chi-Chi, Taiwan, in 1999 give us an experience that a great deal of reinforced concrete structure being damaged at beam-column connections and it also proves that the connections are subjected to extremely flexure stress and shear stress simultaneously and improvement is required to be performed effectively.

SUMMARY OF THE INVENTION

The crux of the present invention is to provide a moment resistance intensified structure with supporting members and a method for intensifying the moment resisting capability. The respective supporting member at an end thereof is attached to a supported member and another end thereof is a moment resisting connection with the supported member to be joined to connection elements at structural moment resisting connection. When the structure is subjected to a load, the supported member occurs deflection due to enduring a bending moment and the supporting member and the supported member generate an action to each other to intensify the moment resisting capability of the frame at the joint. A moment resisting structure having the supporting members can be utilized in a building or bridge of steel frame structure or steel bar reinforced concrete structure or other moment resisting structure or implements.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention can be more fully understood by reference to the following description and accompanying drawings, in which:

Fig. 1a is a diagram showing the bending moment of a rigid frame being subjected to lateral forces;

Fig. 1b is a diagram showing the bending moment of a rigid frame at the horizontal member thereof being subjected to vertical loads;

Fig. 2a is a side view illustrating a “H” cross section supported steel member at both ends thereof being disposed with a channel shaped steel supporting member of the present invention respectively;

Fig. 2b is a sectional view along line 2b-2b shown in Fig. 2a;

Fig. 2c is a sectional view along line 2c-2c shown in Fig. 2a;

Fig. 3a is a diagram illustrating the supported member at both ends thereof being subjected to unidirectional bending moments with supporting member at each of the two ends against deflection, directions of exerting forces and type of the deflection produced at the supported member with the deflection indicated having been exaggerated;

Fig. 3b is a diagram illustrating directions of exerting forces at the supporting members and type of the deflection thereof produced at the supporting members under loading with the deflection having been exaggerated;

Fig. 3c is a diagram illustrating bending moments of the supported member and the supporting member respectively under loading;

Fig 4a is a perspective view illustrating a tube shaped supported member fitting with an inner tube shaped supporting member according to the present invention;

Fig. 4b is a perspective view illustrating a tube shaped supported member fitting with an outer tube shaped supporting member according to the present invention;

Fig. 5a is a perspective view illustrating an H shaped steel supporting member being disposed in a hollow space as a composite member;

Fig. 5b is a side view of Fig. 5a;

Fig. 6a is a top view illustrating a spring being attached to an isolator;

Fig. 6b is a sectional view along line 6b-6b in Fig. 6a;

Fig. 6c is a sectional view along line 6c-6c in Fig. 6b;

Fig. 7 is a diagram of bending moments illustrating bending moments at both ends of the supported member;

Figs. 8a to 8d are plan views illustrating failure mechanisms resulting from plastic bending moments at a joint of the supported member, the support member and a connecting element 26 being subjected to a bending moment load; wherein:

Fig. 8a is a plan view illustrating the supported member at joint A being not possible to produce a plastic rotation angle because of being held by the supporting member in spite of the bending moment having been reached to plastic bending moment;

Fig. 8b is a plan view illustrating a plastic bending moment at the joint A being reached during the supported member and the supporting member being subjected to plastic bending moments;

Fig. 8c is a plan view illustrating a plastic rotation angle resulting from a plastic bending moment being reached at a support position C during the supported member being subjected to plastic bending moment; and

Fig. 8d is a plan view illustrating bending moment between the joint A and the support position C having reached to plastic bending moment;

Fig. 9a is a side view of a channel steel supporting member being disposed at two lateral sides of the web of an H shaped steel supported member respectively with the steel supporting members having an inclining angle with respect to the supported member;

Fig. 9b is a sectional view along line 9b-9b in Fig. 9a;

Fig. 9c is a side view of a supporting member being formed of welded steel

plates as a non-prismatic section member to externally support the H shaped steel supported member;

Fig. 9d is a sectional view along line 9d-9d shown in Fig. 9c;

Fig. 10a is a bending moment diagram of a supported member with both ends thereof being subjected to bending moments along the same direction and one of the two ends being held by a supporting member;

Fig. 10b is a bending moment diagram of a supported member with both ends thereof being subjected bending moments along the same direction and the two ends being held by a supporting member respectively;

Fig. 10c is a bending moment diagram of a supported member with uniform load in which both ends thereof being subjected to bending moments with different directions and one of the two ends thereof being held by a supporting member;

Fig. 10d is a bending moment diagram of a supported member with uniform load in which both ends thereof being subjected to bending moments with different directions and two ends thereof being held by a supporting member;

Fig. 10e is a bending moment diagram of a supported member with concentrated load in which both ends thereof being subjected to bending moments with different directions and one of the two ends thereof being held by a supporting member;

Fig. 10f is a bending moment diagram of a supported member with concentrated load in which both ends thereof being subjected to bending moments with different directions and the two ends being held by a supporting member respectively;

Figs. 11a to 11c each are side views of an H shaped steel supported member

at both ends thereof being held by steel channel supporting members in a way of each lateral side of the supported member being joined to one of the supporting members; wherein:

Fig. 11a illustrates the supporting members hold two directional deflections of the supported member at two ends thereof with identical supporting lengths;

Fig. 11b illustrates the supporting members holding one directional deflection of the supported member at two ends thereof; and

Fig. 11c illustrates the supporting members holding two directional deflections of the supported member at two ends thereof with varied supporting lengths;

Fig. 12a is a side view of a cantilever supported member being provided with supporting members against deflection; and

Fig. 12b is a sectional view along line 12b-12b shown in Fig. 12a.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention discloses a structure, which is provided with supporting members to strengthen a frame against bending moments. A preferred embodiment of the present invention is illustrated in Fig. 2a and it can be seen an H shaped steel supported member 25 at both ends thereof is held by a pair of channel supporting members 29, which are disposed at two opposite lateral spaces of the web 36 in the supported member 25 between the upper and lower flanges 35. Support spots 30 between the supported member 25 and the supporting members 29 transmit the exerting forces with steel isolators 31. Reinforcing steel plates 37, 38 strengthen the supported member 25 and the supporting members 29 at the support spots 30 and reinforcing steel plates 39 strengthen the H shaped steel connection elements 26 at bending moment connecting positions for the exerting force being transmitted without local deformations resulting from stress concentration. Fig. 2b is a sectional view

along line 2b-2b in Fig. 2a and it can be seen a pair of steel angles 34 are fastened to the supported member 25 with bolts 33, and the supporting members 29 and the supported member 25 are joined to connection elements 26 by way of welding to form a bending moment resistant joint between the supporting members 29, the supported member 25 and the connection elements 26. Fig. 2c is a sectional view along line 2c-2c in Fig. 2a and it can be seen the isolators 31 contact the flanges 35 for supporting the supported member 25. When the structure is subjected to loads and the supported member 25 generates deflection due to bending moments, the supporting members resist deflections at support spots, and the supported member and the supporting members exert forces to each other. Joints of the supporting members and the connection elements produce bending moments due to the forces exerting the supporting members so as to intensify the frame at the joints against the bending moments. The forces exerting the supported member make the supported member at the support spots and joints with the joining members being subjected to more uniform bending moments so as to weaken shear stress of the supported member 25 at the joints. The isolators 31a, which contact the web 36 of the supported member 25, offer supports to the supported member 25 to prevent the supported member from lateral deflection or twist.

Referring to Fig. 3a, a deformation line of the supported member 25 and actions 15a, 15b of the supporting members against the deflection are illustrated in case of the frame in the embodiment shown in Fig. 2a being subjected to bending moments. Both ends A, B of the supported member are made a tangent 11a, 11b along the deflection line respectively and the offsets 13a, 13b deviating from the tangents 11a, 11b are deflections of the supported member 25 at the support spots 30a, 30b. The deflections are designated as Δma and Δmb. Fig. 3b shows shapes of deflection lines and actions 16a, 16b while the supporting members 29 in the frame shown in Fig. 2a are subjected to the actions 15a, 15b of the supporting members 29. Tangent 12a, 12b are made from the two ends A, B along the deflection lines of the

supporting members 29 respectively and offsets 17a, 17b deviating from the deflection lines are deflections of the supporting frames 29 at support spots 30a, 30b. The deflections of the supporting members 29 are designated as Δsa and Δsb. Fig. 3c shows the supported member has the bending moment 43 being transited between the joints and the support spots while the supporting members resist the deflection of the supported member. That is, the bending moments at the joints become decreasing and at support spots become increasing such that bending moments between the joints and the support spots become more uniform. Thus, the supported member with the supporting member can endure greater bending moments from the joints till the supported member wherever thereof is subjected to a bending moment reaching a value equivalent to a designed bending strength M. At this time, the bending moment Ms to which the supporting member is subjected is a component vector of the action vertically acting each supporting member times a distance between each support spot and each connection element. Because the structural deflection offset is much smaller than the support spot and the connection element, Ms approximates actions exerting each supporting member times the distance between the support spot and the connection element. The bending moment, which is resisted by the supported member and the supporting members, is M + Ms and the frame at joints thereof can have the bending strength with an increment Ms.

Referring to Figs. 4a and 4b, a support spot of a supporting member 29 corresponding to the supported member 25 are illustrated. It can be seen in Figs. 4a and 4b that the supporting member and the supported member are a circular tube respectively. Fig. 4a shows the supporting member 29 is received in the supported member 25 and Fig. 4b shows the supported member 25 is received in the supporting member 29. Both the supported member 25 and the supporting member 29 are fixedly attached to the connection element 26 with a weld joint 28 to form a bending moment resistant frame. The isolator 31 is connected to either the supported member 25 or the supporting member 29 so as to keep the supported member 25 being apart

from the supporting member 29 and to transmit action force. Two isolators are disposed at the support spot 30 and enable the supporting member 29 to support deflections of the supported member at two directions along a plane of the frame.

Fig. 5a shows a I shaped steel supporting member 29 is received in a hollow space of a steel reinforced concrete box shaped supported member 25 and the support spot is provided with isolators 31 for transmitting the action force. Fig. 5b is the side view of Fig. 5a without showing the reinforcing bars. The connection element is composed of the reinforced concrete connection element 26 and H shaped steel connection element 26a so that the supporting member 29 connect with the connection element against the bending moment.

When the structure is subjected to loads, relative displacement of the support spot to the action force between the supporting member and the supported member can be derived an equation. The equation allows the present invention to analyze the structure with conventional art. There are three types of distances between the supporting member and the supported member for deriving a relationship equation for deflection of the supported Δm member and deflection of the supporting member Δm at the support spot:

The supporting member contacts with the supported member at the support spot but there is no action force prior to load exerting between the supported member and the supporting member. Once the supported member is subjected to the load and occurs bending deformation, the supporting member produces an action to the supported member. The relationship equation of the displacement is:

$$\Delta_m = \Delta_s$$

There is a clearance S_1 between the supporting member and the supported member and the supporting member does not act a force to the supported member till the supported member is subjected to a load and occurs bending moment

deformation to touch the supporting member. The equation of displacements related to the supporting and supported members is:

$$\Delta_m = \Delta_s + S_1$$

The supporting member contacts the supported member at the support spot with an action force and the force becomes greater at the time of the supported member being subjected to a load and occurring bending moment deformation. It can be implemented by that a force with the same direction as the predicted deflection is applied in advance while the supporting member is mounted. In this way, the supporting member has a displacement S_2 to result in constraint before the supported member being mounted. The supporting member can apply a force to the supported member as the constraint is released so that the supported member has already had an action before being subjected to a load. An equation of displacements related to the supporting and supported members is:

$$\Delta_m = \Delta_s - S_2$$

The support spot can be added with isolators such as iron or rubber pieces. The isolators connecting with either the supporting member or the supported member are made and joined to transmit the action force between the supporting member and the supported member. For instance, an H shaped steel member is attached with steel plate isolators by way of welding.

In case of elastic isolators such as rubbers and springs being utilized, the isolators can be compressed while the supporting member resists the deflection of the supported member. The deformation S_3 along the direction of the action and the action has a specific relationship. The equation of displacements of supporting and supported members is:

If the support spot is arranged with isolators and the supporting member and

the supported member contact with the isolators under a condition of no force acting the supported member before load exertion, the equation related to the displacements is:

$$\Delta_m = \Delta_s + S_3$$

If isolators and clearance S_1 are between the supporting member and the supported member, the clearance S_1 disappears during the supported member being subjected to load and occurring bending moment deformation before the supporting member acting a force to the supported member, the equation related to the displacements is:

$$\Delta_m = \Delta_s + S_1 + S_3$$

If supporting member and supported member exist acting force prior to load applied, and pre load force cause deformation S_2:

$$\Delta_m = \Delta_s - S_2 + S_3$$

In case of the rubber isolator being utilized, the energy can be dissipated during the isolator being subjected to a force repeatedly and in case of the spring isolator being utilized, the energy can be stored during the isolator being subjected to a force and the stored energy can be released once the exerting force is eliminated.

Fig. 6a is a top view illustrating a spring isolator being used in a structure composed of a welded box supporting member 29, a welded box supported member 25 and a welded connection element 26.

Fig. 6b is a sectional view along line 6b-6b shown in Fig. 6a and it can be seen that an iron tube piece 32a is fastened to the spring 32 by way of a bolt 32c to form an isolator. The spring 32 at another end thereof is joined to the supporting member 29 by way of another bolt 32c. The iron tube piece 32a is not joined to the supported

member 25 and four iron flat pieces 32b are welded to the supported member 25 to locate the iron tube piece 32a in place so as to prevent the iron tube piece 32a from side movement.

Fig. 6c is a sectional view along line 6c-6c shown in Fig. 6b and it can be seen that the box shaped supporting member 29 is received in the box shaped supported member 25 and the spring 32 is attached with the iron tube piece 32a by a bolt 32c.

Further, the present invention makes magnitude of maximum bending moment from the joint of the supported member and the connection element to that at the support spot being uniform such that more plastic areas of the members are able to occur. A structure is taken as an example in which a lateral force is exerted to result in the members at both ends thereof being subjected to bending moments in the same direction. Fig. 7 illustrates a bending moment diagram to explain a method for selecting support spots and cross sections thereof in the embodiment shown in Fig. 2. The supported member at both ends A, B thereof is subjected to bending moments and a distance L_1, L_2 away from the both ends is supported by a supporting member respectively. L_3 is a length of L_1, L_2 being deducted from length L of the supported member 25. In case of bending moments at the both ends A, B of the supported member and support spots C, D reach allowable bending moment M, it is known that shear force between C and D is a value $2M/(L-(L_1+L_2))$. In order to meet the requirement of the shear stress endured by the supported member being not over the design shear strength V, the condition is:

$$2M/(L-(L_1+L_2)) < V, \text{ that is,}$$

$$(L_1+L_2) < L-(2M/V)$$

The equation can decide upper limit length of the supporting member and it can be applied to the distance of either L_1 or L_2 is zero, namely, it is in a condition of only having one support spot. According to the conventional art, it is necessary to

move the plastic hinge to a distance greater than one half depth of the beam. Hence, based on the principle, the support spots at the supporting member are provided with a distance greater than one half depth of the beam away from the connection element.

A relationship of displacement between the supported member and the supporting member with respect to the support spot C is:

$$ML_1^2/(2EI)=M_{s1}L_1^2/(3EI_1)+(P_1L_1/(G_1A_{s1}))$$

wherein, I is the moment inertia of the supported member, M_{s1} is the bending moment of the supporting member at the joint A, P_1 is the action force at point C between the supporting member and the supported member at point C, I_1 is a moment inertia of the supporting member at point C, G_1 is a shear modulous of the supporting member and A_{s1} is a cross section of the supporting member at point C for resisting shear force. $ML_1^2/(2EI)$ is a deflection of the supported member resulting from bending moment, $M_{s1}L_1^2/(3EI_1)$ is a deflection of supporting member at point C resulting from bending moment and $P_1L_1/(G_1A_{s1})$ is a deflection of the supporting member at point C resulting from shear force. It can obtain

$$I_1=2I\,M_{s1}L_1^2(G_1A_{s1})/(3(ML_1^2G_1A_{s1}-2EI\,P_1L_1))$$

Since $M_{S2}=P_1L_1=2ML_1/L_3$

$$I_1=4IL_1^2G_1A_{s1}/(3(G_1A_{s1}L_1L_3-4EI))$$

Similarly,

$$I_2=2IM_{s2}L_2^2(G_2A_{s2})/(3(ML_2^2G_2A_{s2}-2EIP_2L_2))$$

Since $M_{S2}=P_2L_2=2ML_2/L_3$

$$I_2=4IL_2^2G_2A_{s2}/(3(G_2A_{s2}\,L_2\,L_3-4EI))$$

Wherein, M_{s2} is bending moment of the supporting member at joint B, P_2 is reaction force between the supported member and the supporting member at point D, I_2 is the moment inertia of the supporting member at point D, A_{s2} is the cross section area of the supporting member at point D for resisting shear force. When the supporting member provides moment inertia I_1, I_2 and the bending moments of the supporting member at points C and D are design moment resisting strengths M, the bending moments of the supported member and the supporting member joining at joints A, B with the connection elements are maximum values, which are $M+M_{s1}$ and $M+M_{S2}$. Because $M_{s1}:M_{S2}=L_1:L_2$, the longer the supporting member is, the greater the subjected bending moment is. Hence, locations of support spots can be decided by magnitudes of bending moments at both ends of the supporting member.

It is a preset state that the members at the joints A and B and support spots C and D have bending moments reaching design moment strengths M at the same time. Once force subjected condition is changed, the state will not occur. When bending moment at support spot D is $(1-X)M$, the bending moment of the supporting member and the supported member at joint A with the joining member is $M+M_{S3}$ and the bending moment subjected by the supported member is less than M. In order to have the bending moment of the supported member being equal to M, a supporting member with moment inertia less than I_1 can be utilized and the smaller moment inertia can be found by way of displacement relationship of bending moment M_{S3} of the supporting member at joint A. When the supporting member, which is provided with the moment inertia, has a bending moment being between (1-X)M and M at the support spot D, the bending moment at joint A can reach the design moment strength M earlier than the support spot C and it is preferable that provision of cross section strength of the supporting member is capable of preventing the supported member from reaching plastic moment before bending moment of the support spot C reaching plastic moment.

Figs. 8a to 8d illustrate failure mechanism resulting from plastic moment at the joint of the supported member 25, the supporting member 29 and connection element 26 and show the members having rotation angles and deflections due to plastic moment. Black dots 50 in the figures indicate plastic moments have been reached at these spots. Fig. 8a shows although bending moment of the supported member 25 at the joint A has reached plastic moment, no plastic rotation angle occurs due to being supported by the supporting member 29. Fig. 8b shows once the bending moment of the supported member 25 at the joint A has reached plastic moment, additional bending moment at the joint A is supported by the supporting member 29 and the reaction between the supported member 25 and the supporting member 29 increases accompanying with the additional bending moment till the bending moment of the supporting member 29 reaching to the plastic moment such that a plastic rotation can occur and the joint is not possible to endure greater bending moment. Fig. 8c shows once the bending moment of the supported member 25 at the support spot C has reached to the plastic moment, it results in a plastic rotation and the support spot C is incapable of endure more bending moment. Fig. 8d shows once bending moment of the supported member 25 at the joint A has reached the plastic moment, additional moment at joint A is supported by the supporting member 29 till bending moment of the supported member 25 at the support spot C reaching the plastic moment and the supported member 25 between points A and C is subjected to the plastic moment which result in a sector of plastic hinge and attain an ideal structural plastic behavior. The criteria for providing the supporting member is bending strength thereof is capable of preventing plastic moment of the member being reached before the bending moment at support spot C reaching plastic moment.

The supporting member also can contact the supported member directly without isolators in between. For example, Fig. 9a shows an H shaped steel supported member 25 at two lateral sides of the web thereof is supported by a channel shaped supporting member 29. Fig. 9b is a sectional view along line 9b-9b in

Fig. 9a. Fig. 9c shows that the H shaped steel supported member 25 at the direction enduring the bending moment deflection is supported by another H shaped supporting member 29. Fig. 9d is a sectional view along line 9d-9d in Fig. 9c. Deflection at the support spot due to being subjected to reaction can be figured out by conventional art or can be obtained by way of test.

The present invention can be applied to the supported member with bending moments at both ends thereof having the same direction, namely, tensile stresses at the two ends being at opposite sides of the supported member. For example, Fig. 10a shows the structure occurs bending moment during being subjected to lateral load such as earthquake force or wind force. The present invention also can be applied to the supported member with bending moment at two ends thereof being different in direction, namely, tensile stresses at the two ends thereof being at the same lateral side. For example, Fig. 1b shows bending moment occurs at a horizontal member, which is subjected to vertical load.

Figs. 10a to 10f are bending moment diagrams of the supported member in a structure. Two ends of the member are designated as A and B respectively and when a supporting member is provided at end A, there are three types of providing another supporting member at end B: (1) having support with the same direction as end A; (2) having support with a direction different from end B; and (3) no support provided. The bending moment is drawn at tension side of the supported member in each of Figs. 10a to 10f and the respective supported reaction 15 results in the bending moment diagram 43 having bent at the respective support spot.

Fig. 10a shows bending moments at both ends of the supported member have the same direction and bending moment diagram 43a is formed due to the supported member at an end thereof being supported with a supporting member. Fig. 10b shows bending moments at both ends of the supported member have the same direction and bending moment diagram 43b is formed due to the supported member

at both ends thereof being supported with a supporting member respectively.

Fig. 10c and Fig. 10e show the respective supported member being supported with a supporting member at an end thereof with bending moments at both ends of the supported member having different directions and the bending moment diagrams are 43c and 43e respectively. Fig. 10d and Fig. 10f show the respective supported member being supported with a supporting member at both ends thereof with bending moments at both ends of the supported member having different directions and bending moment diagrams are 43d and 43f respectively. For instance, for a long span member being subjected to vertical load and both ends of the member enduring extremely large bending moments, these support types can be adopted.

It is noted that Figs. 10c and 10d illustrate a uniform load is exerted to the respective supported member and Figs. 10e and 10f illustrate a concentration load is exerted to the respective member. One of situations, which result in bending moment at an end thereof being larger and adopting a support spot, is that bending moment caused by the horizontal member being subjected to structural lateral load and vertical member load. The combination effect leads to bending moment resulting from structural lateral load and bending moment resulting from member vertical load being the same direction so that the added bending moment becomes larger. Bending moments at another end are different directions so that the subtracted bending moment becomes less.

Lateral load such as earthquake force or wind force has two opposite directions to the structure being subjected to a force at the frame plane thereof and bending moments caused also have opposite directions to be counted in design. In addition, bending moments at both ends of the member resulting from load on the member such that it causes different strength requirements in different directions for resisting deflections and provision of supporting member becomes different. Fig. 11a shows the supported member 25 at two opposite lateral directions is supported with a

supporting member 29 with identical support length. The present embodiment is suitable for situation of being subjected to load and support reaction as shown in Fig. 10b.

Fig. 11b illustrates the supporting member 29 is only arranged at a lateral side of the supported member 25 against deflection of the supported member 25. The present embodiment is suitable for a situation of being subjected to load and support reaction as shown in Figs. 10a, 10c, 10d, 10e or 10f against deflections to allow the structure enduring bending moments caused by horizontal forces along two opposite directions.

Fig. 11c illustrates the supporting member 29 is arranged at two lateral side of the supported member 25 against deflection of the supported member 25 with different support lengths. The present embodiment is suitable for a situation of being subjected to load and support reaction as shown in Fig. 10b with bending moments at both lateral sides of the supported member being different from each other.

A further embodiment shown in Fig. 12a illustrates a cantilever H shaped supported member 25 at two lateral spaces of the web, which joined to the upper and lower flanges, is supported with a pair of channel shaped supporting members 29 respectively with steel isolators 31 at the support spot 30 being welded to the supporting member 29 and contacting flanges 35 of the supported member 25 and steel isolators 31a at the support spot 30a being welded to the supported member 25 and contacting the web 36 of the supporting member 29. A steel bottom plate 41 is fixed to a steel bar reinforced concrete base 43. The supported member 25 and the supporting member 29 are welded to the steel bottom plate 41 and the steel bottom plate 41 is fastened to the base 43 with bolts 42 to constitute bending moment resistant connection. Once deformation happens to the supported member 25, the supporting member 29 can transit an action against deformation via the steel isolator 31 or 31a. Fig. 12b is a sectional view along line 12b-12b in Fig. 12a.

While the invention has been described with reference to preferred embodiments thereof, it is to be understood that modifications or variations may be easily made without departing from the spirit of this invention, which is defined by the appended claims.